

Seismic

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Project Title:

Bridge Design for Earthquake Fault Crossings: Synthesis of Design Issues and Strategies

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This project verified the reliability of the Fault Rupture-Response Spectrum Analysis and Fault Rupture-Linear Static Analysis methods to estimate the displacement responses of curved bridges.

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Designing Bridges Crossing Earthquake Faults

Developing practical analysis procedures to estimate bridge rupture response to seismic activity

WHAT WAS THE NEED?

Bridges that cross earthquake faults can be more vulnerable to damage than those located on one side of the earthquake fault. Although avoiding building bridges across earthquake fault zones might be the best design strategy, it is not always possible to do so in regions of high seismicity, such as California. Response History Analysis (RHA), a rigorous nonlinear method that uses spatially varying ground motions based on site-specific seismological studies, can be conducted, but this procedure typically requires extensive modeling and computational efforts, making it less practical for bridge engineers.

In response to the absence of practical analysis methods for bridges crossing fault rupture zones, a previous Caltrans study developed and validated two simplified procedures, Fault Rupture-Response Spectrum Analysis (FR-RSA) and Fault Rupture-Linear Static Analysis (FR-LSA), as alternatives to the exacting Response History Analysis (RHA) approach. The initial validation of these procedures was performed on ordinary straight bridges. However, a significant number of California bridges have features that differ from those that were tested. Further evaluation of the adequacy of the simplified analysis procedures is urgently needed in the context of representative actual bridges, particularly curved bridges. In addition, a critical knowledge gap exists in implementing the approximate procedures in practical design.

WHAT WAS OUR GOAL?

The goal was to verify the reliability of simplified procedures to estimate the displacement responses for curved bridges that cross earthquake faults and to document the results for Caltrans Seismic Design Criteria.



Selected three-span bridge

WHAT DID WE DO?

Caltrans, in partnership with the California Polytechnic State University College of Engineering, selected two curved bridges—three-span and four-span—that represent typical California construction. The selected bridges were assumed to cross strike-slip fault ruptures. Numerical models of the selected bridges were developed using Open System for Earthquake Engineering Simulation (OpenSees). The adequacy of the FR-RSA and FR-LSA procedures was then examined by comparing the results with the more rigorous RHA procedure. A set of 10 ground motion records, which include a relative fault offset of 100 cm, were used in this investigation.

The ground offset was determined to place bridge bents well into the inelastic range while not so large as to completely dominate the contribution of the dynamic response. The bridge displacement response quantities extracted for validation purposes included abutment longitudinal displacement, abutment transverse displacement, and resultant bent drift. Other parameters considered in the numerical models and varied in the analysis include abutment longitudinal stiffness, bridge-to-fault angles, and fault locations.

WHAT WAS THE OUTCOME?

The research produced the following results based on the numerical simulations conducted:

- Analysis results from both three-span and four-span bridges demonstrated that the quasi-static response alone, which is caused only by ground displacement offset, is inadequate in estimating the bridge response.

- The FR-RSA procedure consistently provides reasonable demand estimates in all considered cases accounting for different numbers of bents, longitudinal abutment stiffness values, fault locations, and fault-to-bridge angles. The results are close enough to those from the RHA method for representative curved bridges crossing fault ruptures.
- The FR-LSA method provides reasonable results for the three-span bridge, but predicts overly conservative demand estimates for the four-span bridge. Therefore, it is suggested that FR-LSA be used with caution for bridges with more than three spans.

WHAT IS THE BENEFIT?

Based on the results from this investigation, the simplified FR-RSA procedure can be used as an alternative to the nonlinear RHA with multiple support excitation. FR-RSA implemented on CSiBridge provides adequate predictions for bridge responses and can be used in future practice.

LEARN MORE

To view the full report:

www.dot.ca.gov/hq/esc/earthquake_engineering/Research_Reports/vendor/cal_poly/65A0379Final_Report.pdf

Typical OpenSees
result comparisons:
RHA vs. FR-RSA and
RHA vs. FR-LSA

